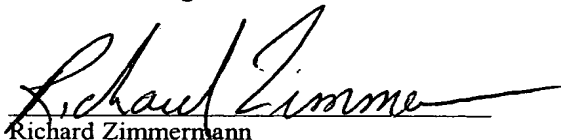


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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
APPLICATION FOR UNITED STATES LETTERS PATENT

Title:

METALLIZED OPTICAL FIBERS AND FERRULES FOR OPTICAL FIBERS FOR
DIRECT ATTACHMENT TO PHOTODIODES

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**METALLIZED OPTICAL FIBERS AND FERRULES FOR OPTICAL
FIBERS FOR DIRECT ATTACHMENT TO PHOTODIODES**

TECHNICAL FIELD

5 A technique for coupling an optical fiber directly to a photodiode is disclosed. More specifically, the technique includes coating a portion of an end of an optical fiber and attaching the optical fiber directly to a metallized surface of a photodiode. As a result, a direct coupling of an optical fiber to a photodiode is achieved without the need for intervening lenses, mirrors or other imaging systems
10 between the fiber end and the photodiode.

BACKGROUND

 Optoelectronic components or active optical devices, in conjunction with optical fibers, are used for optical data transmission and reception, data storage, printing, laser pumps and a multitude of other applications. Data transmission over
15 optical fiber will eventually surpass data transmission over copper wire because of the superior transmission capabilities of optical fiber. Specifically, while copper is reliable, it cannot operate at high signal transfer rates. For data transfer rates exceeding 50 Mb/s, special systems copper wiring is required. For data transfer rates over 150 Mb/s, use of even the best copper wiring available is questionable.

20 Optical fiber, on the other hand, can handle data transmission rates hundreds of times that of copper. For example, current optical fiber systems can easily handle 40 Gb/s over a single fiber. And advances in technology will only result in increases in data transfer rates over a single fiber.

 As a result, to meet the data transfer rate demand generated by the
25 dramatic increase in Internet users, related bandwidth intensive applications, virtual private networking (VPN), storage area networking (SAN) and other rich media streaming over the Internet, telecommunications carriers have designed and installed new networks based upon optical fiber, have deployed additional fiber in their existing networks and have used advances in optical technologies such as dense
30 wavelength-division multiplexing (DWDM).

In all communications networks relying upon the use of optical fiber, the fibers must be coupled to optoelectric components, such as light emitting devices and light receiving elements. Typically, the communication path is in the form of an optical fiber, the ends of which are coupled to light transmitting and light receiving
5 elements. In order to assure maximum optical coupling between the ends of the fibers and the optical devices to which they are coupled, it is important to precisely fix the axial distance between the end of the fiber and the face of the optical element to which it is to be coupled as well as accurately aligning the end of the fiber with the prescribed location on the surface of the light emitting or light receiving element.

10 Further, with respect to the coupling of an optical fiber to a photodiode, currently available coupling devices are bulky, complex and incur a high cost of manufacture while failing to provide the compact size needed for current and future optical system components. For example, a typical photodiode optical fiber ferrule attachment requires an imaging lens, a mirror or both, all disposed between the
15 fiber and the photodiode detector. Further, a two or three dimensional photodiode-fiber alignment process is required in order to optimize the coupling efficiency. Thus, this process is complicated and costly especially for single-mode fiber application where accurate alignment is required.

Therefore, there is a need for an improved method for coupling
20 photodiodes to optical fibers which achieves the requisite coupling efficiency and which lowers the manufacturing costs by providing a less complicated process.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosed methods for coupling optical fibers to photodiodes and
25 disclosed optoelectronic components incorporating the same are described more or less diagrammatically in the accompanying drawings wherein:

Fig. 1 is a perspective view of an end of an optical fiber that extends through a ferrule and with a distal portion that is metallized for direct connection to a photodiode in accordance with this disclosure;

30 Fig. 2 is a front plan view of a back-illuminated photodiode for use in the disclosed methods and disclosed optoelectronic components;

Fig. 3 is a rear plan view of the photodiode disclosed in Fig. 2;

Fig. 4 is an end view of the metallized fiber shown in Fig. 1 as directly coupled to the rear side of the photodiode shown in Figs. 2 and 3; and

Fig. 5 is a plan view of the fiber, ferrule and back-illuminated
5 photodiodes shown in Figs. 1-4 with the front side of the photodiode (see Fig. 2) coupled to a substrate which, in turn, is coupled to a transimpedance amplifier (TIA) on an opposite side thereof.

DETAILED DESCRIPTION OF THE
PRESENTLY PREFERRED EMBODIMENTS

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Fig. 1 is a perspective illustration of a metallized optical fiber ferrule
10 made in accordance with this disclosure. An optical fiber 11 extends through a
ferrule 12 and terminates at a distal end 13. The fiber 11 includes a core 14 initially
disposed within a cladding (not shown) which, in turn, is initially disposed within a
15 buffer (not shown). The cladding and buffer have been stripped off of the core
upstream of the ferrule 12 by techniques that are known in the art. The flat distal end
13 of the fiber 11 or the facet 13 is coated with an annular metal layer that essentially
covers the buffer 16. Optionally, the distal portion 17 of the fiber 11 that extends
beyond the ferrule 12 may be coated with a metal layer as well as shown in Fig. 1.

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Turning to Fig. 2, the front side 21 of the photodiode 20 may be
equipped with an anode 22 and a cathode 23 which, as shown in Fig. 3, extends to the
backside 24 of the photodiode 20. Referring back to Fig. 2, the anode 22 encircles the
active area 25 of the photodiode 20 through which light is received for conversion to
electrical current or an electrical signal. In order to effectively couple the photodiode
25 20 to the fiber 11, at least part of the core 14 of the fiber 11 must be aligned in the
active area 25. The cathode 23 comprises a metal layer which extends over the rear
side 24 of the photodiode 20 but, of course, does not cover the active area 25. The
cathode metal pattern of rear side 24 should be designed such that it can match the
metal pattern on the fiber end for the self align process.

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As shown in Fig. 4, to couple the fiber 11 to the photodiode 20, all that
is required is a single rough alignment of the fiber core 14 with the active area 25.

Specifically, with the rear side 24 of the photodiode 20 facing the end facet 13 of the fiber 11, the core 14 of the fiber and the active area 25 of the photodiode are aligned and pressed into engagement with one another so that the stripped fiber 11 is in abutting engagement with the metallized rear side 24 of the photodiode 20. Then,
5 with the core 14 of the fiber 11 aligned with the active area 25 of the photodiode 20, the combination is heated to a point where the annular metal layer covering an annular portion of the core 14 and the metal layer covering the rear side 24 of the photodiode reflow and the surface tension created by the reflowed metal results in the alignment being maintained or self-alignment during the subsequent cooling. After cooling, the
10 metallized fiber 11 and photodiode 20 are butt-coupled together.

As shown in Fig. 5, a TIA chip 30 may be combined with the photodiode 25 by using a substrate 31 with printed electrical connection lines electrically connecting the TIA chip to the photodiode 20. In the embodiment shown in Fig. 5, the TIA chip is mounted to a first side 32 of the substrate 31. The
15 photodiode 20 is mounted to the end facet 13 of the fiber 11 as discussed above. Then, the photodiode is mounted to the second surface 33 of the substrate 21. Additional circuit components 34 may also be included on the substrate 31. One advantage of the embodiment shown in Fig. 5 is the surface mounting of the photodiode 20 and the TIA chip 30, thereby eliminating wire bonds and the undesired
20 parasitic inductance that accompanies the use of wire bonds.

Thus, one method for manufacturing the embodiment shown in Fig. 5 includes: attaching the TIA chip 30 to one side of the substrate 31, the substrate being equipped with printed electrical connection lines for electrically connecting the TIA chip 30 to the photodiode chip 20; attaching any additional electrical components 34
25 to the side 32 of the substrate 31 on which the TIA chip 30 is attached; coating the stripped fiber 11 coated with at least an annular coating of metal to form an end facet 13 of the core 14 as shown in Fig. 1; optionally, coating the distal portion 17 of the core 14 with metal also as shown in Fig. 1; the moving rear side 24 of a back-illuminated photodiode 20 into abutting engagement with the end facet 13 of the fiber
30 11 with the core 14 of the fiber 11 in alignment or registry with the active area 25 of the photodiode 20 as shown in Fig. 4; carrying out a reflow process under

temperatures sufficient to reflow the metal providing the annular coating on the end facet of the fiber 13 (and the distal portion 17 of the core 14 if it is also coated) and the metal coating on the rear side 24 of the photodiode 20 to reflow the metal together in order to bond the photodiode 20 to the end facet 13 of the core 14 as shown in Fig.

5 5; cooling the assembly to secure the photodiode 20 in place on the fiber 11; and, mounting the photodiode 20 to the other side 33 of the substrate 31 as shown in Fig. 5. In addition to the reflow processes discussed above, the metal layers on the end facet 13 of the fiber 11 and rear side 24 of the photodiode 20 may also be used as solder layers or brazing layers.

10 The metallized layers on one or more of the end facet 13 and distal portion of the core 14 and rear side 24 of the photodiode 20 may be deposited using physical vapor deposition (PVD) techniques such as screen printing or other suitable processes such as sputtering or evaporation. The conductive material used for the metallized layers may include metal such as copper, gold, tin, copper/tin alloys,
15 tungsten, lead, nickel, palladium, KOVAR® or other similar metals. Because the metallized layers are used for soldering, brazing or reflow processes, thick film deposition techniques are preferred. Preferably, the metallized layers would have thicknesses of about 10 μm . However, if desired, thin film metallization techniques may also be employed.

20 Thus, the disclosed methods and embodiments simplify the attachment process or coupling process between a fiber 11 and a photodiode 20. Two-dimensional or three-dimensional active alignment processes are no longer necessary and, instead, a single alignment between the fiber 11 and active area 25 of the photodiode chip is all that is necessary. The annular coating or donut pattern of metal
25 on the end facet 13 of the core 14 can be applied using conventional screen printing techniques. In essence, the disclosed methods utilize surface mount technology to achieve a high accuracy alignment. The disclosed methods take advantage of the alignment properties and surface tension aerated during the melt of reflow process which enable the photodiode 20 and fiber 11 or core 14 to be aligned passively.

30 In the foregoing description, the disclosed structures and manufacturing methods have been described with reference to exemplary

embodiments. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of this disclosure. The above specification and figures accordingly are to be regarded as illustrative rather than restrictive. It is therefore intended that the present disclosure
5 be unrestricted by the foregoing description and drawings, except as may appear in the following appended claims.